Highway Materials Research Laboratory
132 Graham Avenue, Lexington 29, Kentucky

October 15, 1947

File: S-1-3-2

Memorandum to Dean D. V. Terrell
Director of Research

Throughout the past summer the Research Laboratory was very actively engaged in sampling soils from pumping and non-pumping locations on concrete pavements in all parts of the state. This was done as the field portion of work which we refer to as Project S-2 entitled "A Study of the Relationship Between Subgrade California Bearing Ratios and Pumping of Rigid Pavements", for which the attached outline of proposed research was prepared. This outline was drawn up last April and transmitted to Mr. Bray by a memorandum dated April 26. Not only did the outline serve as a general description of the operations which were contemplated, but also it provided a basis for approval of the project by the Public Roads Administration in order that this could qualify for Federal Aid under the 1½ per cent funds allocated for research.

Our primary objective in having Federal Aid on this endeavor was not financial but rather the establishment of joint responsibility for the work, thereby increasing the possibility of agreement on the significance of results and their application to future designs. Approval of the undertaking as Kentucky Project SWHP 1(9) was received in July, but prior to that time (mid May) field work was started. By the last of August when all field operations were completed, 215 locations representing 475 miles of pavement had been sampled, these being divided almost equally between pumping and non-pumping situations. Laboratory testing was carried out as much as possible in conjunction with the field sampling, however limited personnel and more so lack of sufficient C.B.R. equipment (most of which was ordered in May but not received until early September) hampered the laboratory work to the extent that not quite 50 C.B.R. tests were completed by the first of September.

By concentrating on this project during the past 1½ months we have been able to increase that total to approximately 125 C.B.R. tests complete, and all other laboratory tests related to the bearing values, or necessary to classify the soils, are being brought up at such a rate that we expect to have the equivalent of 150 samples tested for all properties by November 1. The entire project including the final written report is scheduled for completion by the end of this year or very shortly thereafter.

For the present, and especially for the Research Board Meeting on October 27, it is desirable that progress on the work be reported. This we intend to do by an oral presentation supplemented by tabulation of data which will be prepared and given by Mr. R. F. Baker, who has been in active charge of the project throughout. Our reason for an oral rather than a written report at this meeting is the utilization of time for laboratory testing, and also the requirements for our study of flexible bases which is another project being conducted simultaneously by the soils section of the Laboratory.

Since the outline for this project has been sent to only a few members of the Research Board heretofore (there having been no meeting since the project was originated), this is being distributed now in order to provide background for the oral report which will be given at our meeting this month. I know that the project is considered of primary importance by the Division of Design, and it should be of almost equal importance to the highway industry in general because the application of bearing values to the problem of pumping is a procedure originated by the Testing Laboratory in Kentucky and knowledge of it is not general. Certainly nothing has been published on the subject. While we are not yet certain of the relationships that will finally be shown by this work, we are reasonably certain that it is the most thorough investigation attempted anywhere, particularly from the standpoint of emphasis placed on specific properties of materials involved rather than on generalities and the spectacular features of pumping.

Respectfully submitted,

L. E. Gregg

L. E. Gregg
Associate Director of Research

Copies to: Research Board Members

Commonwealth of Kentucky
Department of Highways

Outline of Research Proposed
for

A STUDY OF THE RELATIONSHIP BETWEEN SUBGRADE CALIFORNIA BEARING RATIOS AND PUMPING OF RIGID PAVEMENTS

by
The Highway Materials Research Laboratory
Lexington, Kentucky

April, 1947

File: S-1-3-2

I. Purpose

The purpose of this investigation is to determine the relationship between the pumping of rigid pavements and the modified California Bearing Ratio of the subgrade soil beneath the pavement. Ultimately, the objective is to combine data from this research with those from other related studies and provide a design criteria for eliminating or minimizing, in the most economical way, pumping of rigid pavements, particularly when soils of uncertain quality are encountered.

II. Scope

In general, this study will include correlation of soil tests with pumping and non-pumping slabs, particular emphasis being placed on grain size and the CBR. Selection of pavements for study has been based primarily on traffic data that are available. With but few exceptions, only those sections were included on which the 1945 traffic study showed daily more than 500 trucks of all descriptions. However, differentiation of soils for tendency to pump will in-

clude analysis of loads recorded through traffic counts and weight measurements. Performance will be obtained through field surveys, maintenance records, and contacts with district maintenance personnel. Other factors such as transverse and longitudinal joints, construction methods, engineering design (drainage, etc.), relative precipitation, age of pavement, and correlation with soil development will be considered but only in a general way.

III. Methods

Selection of roads to be studied. After careful consideration of the 1945 truck-traffic count, the soil and geologic areas, and the available performance data on pumping pavements, the roads listed in Table I were selected for study. More detailed information is given in Annex 1.

Traffic Analysis. Through cooperation of the Division of Planning, a program has been outlined that will provide for the study a reasonably accurate check on volume and weight of truck traffic. Beginning in June, the Planning Survey will conduct traffic measurements at the following loadometer stations:

	County	Station
1.	Greenup	Jct. U.S. 23 and Ky. 5
2.	*Rowan	Jct. U.S. 60 and Ky. 32
3.	Floyd	Jct. U.S. 23 and Ky. 80
4.	*Letcher	Jct. U.S. 119 and Ky. 15
5.	Rockcastle	U.S. 25 at East City Limits of Mt. Vernon
6.	Fayette	U.S. 60 at East City Limits of Lexington
7.	Fayette	U.S. 60 at West City Limits of Lexington
8.	Boone	Jct. U.S. 25 and U.S. 42
9.	Jefferson	U.S. 60 near Middletown
10.	Jefferson	U.S. 42 at East City Limits of Louisville
11.	*Hardin	Jct. U.S. 60 and U.S. 31-W
12.	*Christian	U.S. 41 at North City Limits of Hopkinsville

Table I

Route No.	Road	Length (miles)	Total No. of Trucks (1945)	Year Paved	Geologic Area	Pumping?
U.S. 41	Tenn. St. Line to Ohio River Bridge	110.0	Varies from 390 to 1736	1930 to 1940	Mississippian Pennsylvanian Alluvium Loess	Some Sections
U.S. 42	From Covington to Louisville	115.0	300 to 812	1929 to 1941	Alluvium Devonian Ordivician	Some * Sections
U.S. 23	Paintsville to Pikeville	20.0	600 to 1026	1927 to 1932	Pennsylvanian	Not in * 1945
U.S. 23	Ashland to Greenup	1.3	2500	1933	Pennsylvanian	Not in * 1945
U.S. 25	Williamstown to Georgetown	25.6	725	1938	Ordivician	Severe in Eden sec. Slight in Trenton section
U.S. 25	Clays Ferry Bridge to Terrill	15.0	900 to 1190	1924 to 1943	Ordivician	Some Sections
U.S. 25	Mt. Vernon to London	11.9	560 to 616	1925 and 1942	Pennsylvanian	Some * Sections
U.S. 31W	Louisville to Elizabethtown	45.0	1000 to 1600	1939 to 1943	Alluvium Pennsylvanian	Some Sections
U.S. 31W	Elizabethtown to Munfordville	7.9	500 to 535	1942 to 1943	Pennsylvanian	Some * Sections
U.S. 60	Louisville to Frankfort	43.5	600 to 1000	1934 to 1942	Devonian Silurian Ordivician	Some * Sections
U.S. 60	Versailles to Lex. to Winch.	27.1	600 to 1250	1921 to 1939	Ordivician	Some * Sections
U.S. 60	Henderson to Morganfield	21.3	570 to 800	1930 to 1943	Alluvium Loess	Not in * 1945
U.S. 60	Brandenburg to Louisville	3.1	405	1932	Pennsylvanian	Not in * 1945
U.S. 60	Grayson to Olive Hill	15.1	372	1926	Pennsylvanian	Not in * 1945
U.S. 150	Louisville to Bardstown	12.8	620 to 940	1920 to 1925	Ordivician	Not in * 1945
U.S. 68	Paducah to Benton	13.4	360 to 550	1933 to 1937	Coastal Plain Alluvium	Not in * 1945
U.S. 68	Hopkinsville to Cadiz	10.2	308	1932	Mississippian	Not in * 1945
U.S. 27	Newport to Alexandria	3.1	720	1941	Ordivician	Not in * 1945
U.S. 27	Somerset to Whitley City	6.3	512	1930	Mississippian Pennsylvanian	Not in * 1945
U.S. 119	Jenkins to Whitesburg	7.5	496	1927	Pennsylvanian	Not in * 1945
U.S. 119	Harlan to Pineville	4.5	552	1926	Pennsylvanian	Not in * 1945

Table I (Con't)

Route No.	Road	Length (miles)	Total No. of Trucks (1945)	Year Paved	Geologic Area	Pumping*
U.S. 45	Paducah to Brookport	1.2			Alluvium	Not in * 1945
U.S. 45	Fulton to Mayfield	4.9	300 to 325	1931	Loess	Not in * 1945
U.S. 51	Fulton to Clinton	6.4	319	1930	Loess	Not in * 1945
Ky. 15	Hazard to Whitesburg	3.1	812	1931	Pennsylvanian	Not in * 1945
Ky. 80	Allen to Lackey	6.0	684 to 722	1934 to 1937	Pennsylvanian	Not in * 1945

Total Length = 531.2 miles

* As noted in 1945 Pavement Condition Survey

	County	Station
13.	Christian	U.S. 41 at South City Limits of Hopkinsville
14.	*Henderson	Jct. U.S. 41 and U.S. 60 West of Henderson
15.	Hopkins	U.S. 41 at West City Limits of Madisonville
16.	McCracken	Jct. U.S. 68 and Ky. 284
17.	*Fulton	Jct. U.S. 51 and Ky. 94

*Denotes permanent loadometer stations.

The traffic analysis, while mentioned here, is not a portion of this study, other than in the application of the data that will be available.

Performance Surveys. The first step in determining the performance record of the various pavements will be through discussion with the Assistant District Engineers of Maintenance. Data will be obtained as to pertinent construction details, as well as information on the existence or non-existence of pumping, and maintenance that may have resulted from pumping.

The road selected for study will then be observed in detail. After a brief reconnaissance intended to indicate the general condition of the road, a detailed survey will be made, considering the following:

a. Location of joints and cracks.
b. Faulting and pumping at joints and cracks.
c. Effectiveness of any corrective measure for pumping.
d. Type of surface drainage.
e. Topography of area.
f. General condition of pavement.
g. Selection of locations for field samples representing typical conditions.

Field Sampling and Testing. Simultaneously with traffic and performance surveys, field sampling and testing will be

initiated at the locations selected. First, a sample of 40 to 50 pounds will be taken from beneath the pavement. This sample will be obtained, principally, by excavating along the edge of the pavement and removing the sample from beneath the slab. In some instances, additional soil will be obtained through core holes.

Cores will be drilled at approximately one-third the sample locations. The main purpose of the core is to obtain a relatively good volume measurement of the subgrade or sub-base. In the other two-thirds cases, a rough volume measurement will be made on a portion of the sample taken from beneath the edge of the pavement. In this latter case, a rough cube or beam will be cut from the soil and weighed immediately. The sample will then be taken into the laboratory for a moisture content determination.

At all locations, a small sample will be placed in an air tight container, for moisture content determination in the laboratory.

Where holes are cored, field densities will be obtained by the sand method.

A forty pound sample representative of the soil in the area will be taken for correlation with the sample taken from beneath the pavement. Depth, horizon, and similar information will be noted. It is doubtful that time will permit a complete analysis of all of these samples.

It is estimated that 250 samples can be processed in the laboratory during a period of about six months. This would average approximately one sample location every two

miles. In general, this may prove to be more than adequate. For instance, on U.S. 25 between Georgetown and Williamstown, a distance of approximately thirty miles, a maximum of five samples appears sufficient.

Laboratory Testing. Routine laboratory tests will be conducted in accordance with ASTM standards as follows:

1. Mechanical Analysis of Soils (D422-39)
2. Liquid Limit of Soils (D423-39)
3. Plastic Limit and Plasticity Index of Soils (D424-39)
4. Shrinkage Factor of Soils (D427-39)
5. Moisture-Density Relations of Soils (D698-427)
6. Specific Gravity of Soils (D854-45T)

Samples will be prepared in accordance with ASTM Method (D421-39). Spot checks of permeability will be conducted on specimens compacted at optimum moisture content and for this, the pressure-saturater type apparatus will be used.

For the most part, the routine soil tests will be adjunctive to the principle analyses; i.e., the determination of the California Bearing Ratio, as modified in past usage by the Testing Laboratory, Kentucky Department of Highways. Specifically, the procedure is as outlined in Annex 2.

Construction and Engineering Details. The original plans and final construction report for the pavement will be obtained through the files of the Kentucky Department of Highways. With additional information from the District Engineers and the performance survey, details such as pavement thickness, drainage, joint spacing, type of joints, construction weather, etc. will be available for evaluation in the final report.

IV. Equipment

Field. No new equipment will be needed specifically for this investigation.

Laboratory. In order to complete this study within a reasonably short time, some new CBR equipment will be necessary. At the present time, only six molds, six perforated plates, and eighteen lead weights are available to the laboratory. This quantity is sufficient for routine testing. However, in order to complete an average of twenty-one tests in ten days, it will be necessary to have fifteen additional molds and plates, and forty-five lead weights. It is estimated that this equipment will cost $600.00.

V. Presentation of Data

All data will be analyzed in the light of previous studies, as well as from the new variable, the CBR. Texture will be presented on a triangular chart similar to that established in studies by Tennessee, North Carolina and Kansas. (Fig. 1) In addition, gradation curves will be plotted for all soil types, so that a more complete picture of particle size will be available. Statistical analyses will be made when applicable.

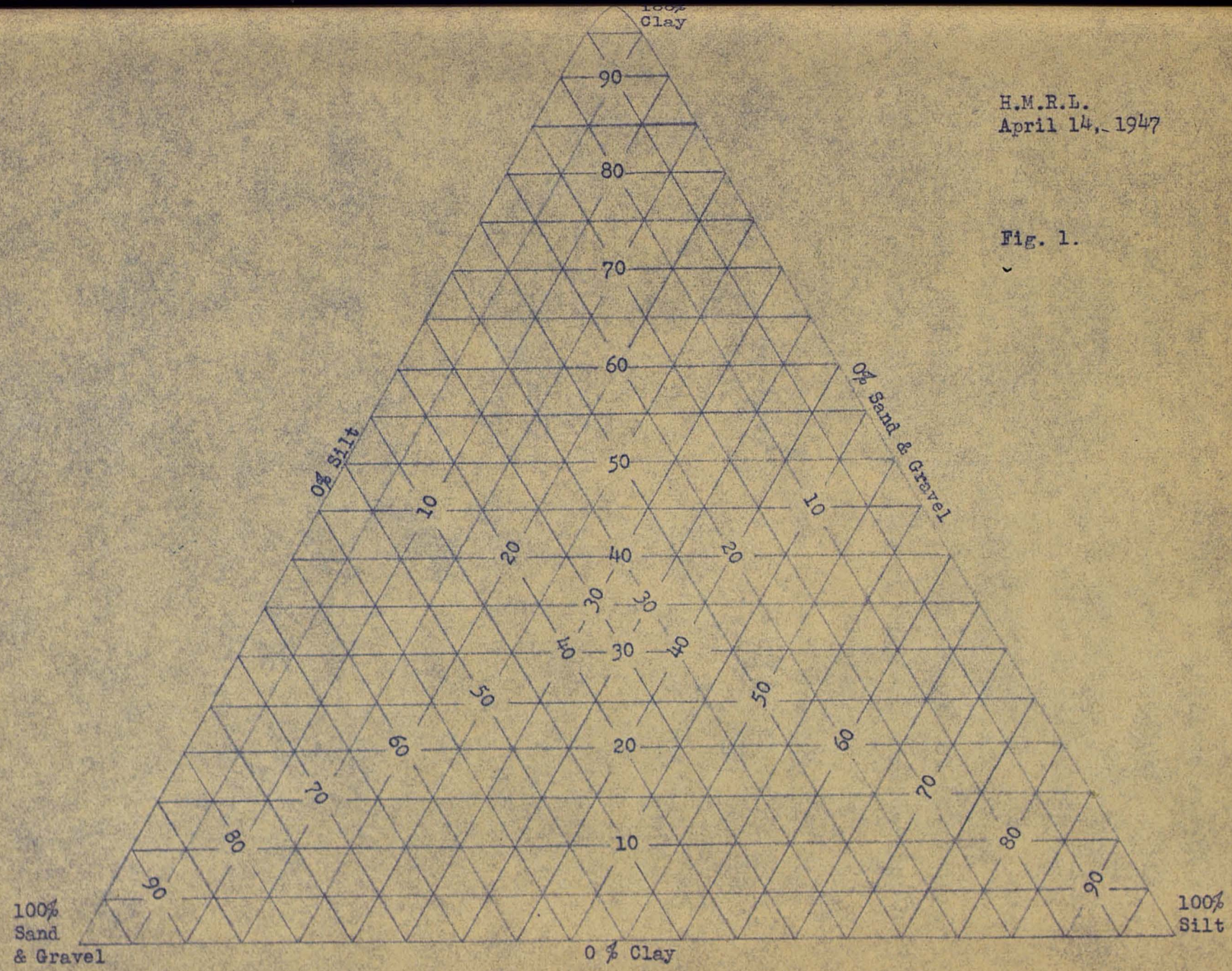
The final report will present all data obtained, and the manner in which it was obtained. A separate section of the report will cover conclusions drawn from the data.

VI. Summary

The main portion of this study will consist of an analysis of the following variables versus pumping:

H.M.R.L.
April 14, 1947

Fig. 1.



1. Traffic - weight and volume
2. Soil - Texture and CBR

In order to estimate their affect, a limited amount of data will be obtained on the following variables:

1. Permeability and capillarity
2. Swell and shrinkage
3. Moisture content variation in the base
4. Density of the base
5. Correlation with soil development
6. Transverse and longitudinal joints

Sampling and testing will be conducted so as to furnish a basis for future investigation of pumping, considering:

1. Base course design and drainage
2. New pavements
3. Maintenance of slabs already pumping.

Annex 1

Table 2 - Detailed Data on Roads Selected

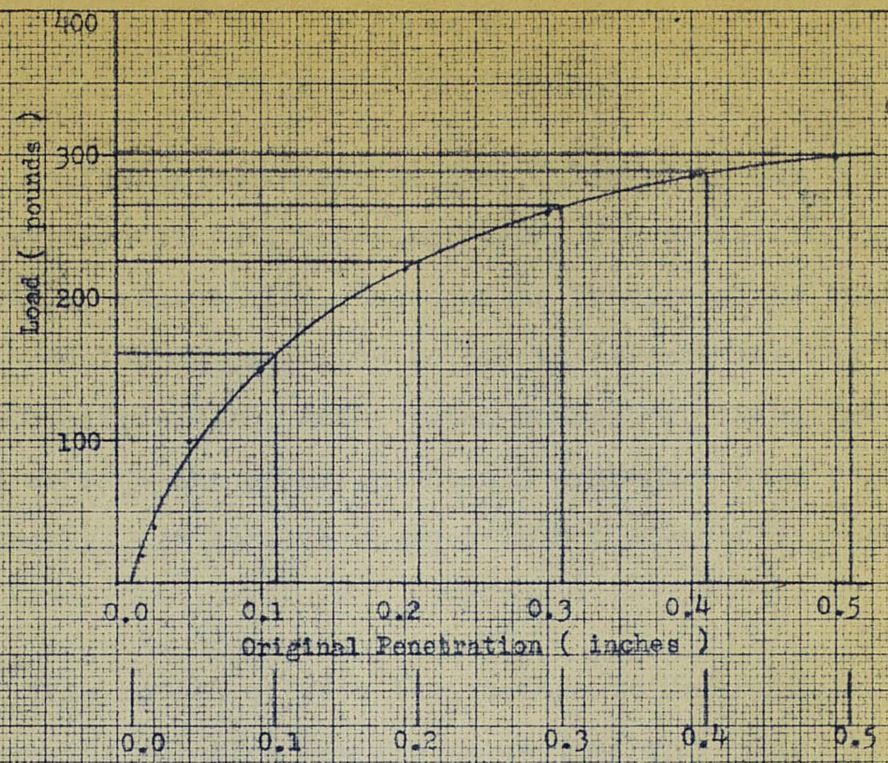
District	County	Code No.	Project No.	Route #	Road	Location	Length	Joints		Year Graded	Year Paved	Truck Traffic			Pumping	Geologic Areas	Soil Area
								Expan.	Contrac.			1938	1945	1947			
1	Hopkins	67	SP 2 FS (Hopkins)	U.S. 41	Madisonville-Evansville	CL Madisonville to NW	2.4	No	No	1924	1930	450	702		Yes	Pennsylvanian	
	Henderson	90	FA 109 BS (Henderson)			Jct. US 60 to SR 266	7.4	No	No	1932	1933	350	650				
		103	SP 8 JS (Henderson)			Jct. US 60 to ½ mi. S.	2.8	No	No	1932	1933	1500	1736				
		194	SP 54-340-1 (Henderson)			3 Mi. West Mad. to Nebo	5.0.	120	60	1940	1940	---	750				
1	Webster	71	FA 34 AS (Webster) FA 34 D2S	U.S. 41	Dixon-Madisonville	Dixon to McGraw Sch.	8.4	No	No	1922	1931	400	442		Yes	Providence Ls.(Penn.)	
		53	FA 134 DS (Webster)			McGraw Sch..to Hop. CL	1.6	No	No	1924	1931	390	468				
	Hopkins	54	FA 41 ABS (Hopkins)			From 2.5 mi. NW of Mad. to Webster CL	.8	No	No	1922	1931	330	418				
		55	FA 41 ABS (Hopkins)				5.1	No	No	1922	1931	330	418				
		56	FA 41 AES (Hopkins)				4.5	No	No	1922	1931	330	418				
1	Webster	85	FA 34 CES (Webster)	U.S. 41	Henderson-Dixon	Dixon-Henderson CL	9.3	No	No	1922	1932	300	390		Yes	Providence Ls. (Allegheny-Carbondale)	
	Henderson	89	FA 109 AS-FA 42 AS			Jct.SR 266-Webster CL	6.0	No	No	1921	1932	300	481				
		90	FA 109-BS (Henderson)			U.S. 60 to SR 266	7.4	No	No	1932	1933	350	650				
1	Christian	151	FA 306 ABCGS (Chris.)	U.S. 41W	Hopkinsville-Clarksville	Hopk.-Tenn. State Ln.	7.1	90	30	1937	1937	---	432		Not in 1945	St. Louis and Fredonia Ls., Mississippian	
		172	FA 306 BCS 2			1.5 mi. S. Hopk.-South	7.7	90	30	1938	1938	---	400				
1	Christian	92	FA 171 AS (Christian)	U.S. 41	Hopkinsville-Madisonville	CL Hopkins-Nr.Crofton	11.5	No	No	1925	1932	350	680		Not in 1945	Pottsville (Penn.) Mississippian	
		192	FA 111 A5 GS			1.5 mi. N.Crof.-Hop.CL	4.6	120	60	1940	1940	---	540				
	Hopkins	84	FA 122 BS 2 (Hopk.) & FA 41 CES 2			Earlington-Christian CL	6.9	No	No	1925	1932	500	598				
1	McCracken			U.S. 45	Paducah-Brookport	Pad.-Ohio River Bridge	1.2									Pliocene and Loess	
1	Fulton	64	FA 146 BS (Fulton)	U.S. 45	Fulton-Mayfield	Fulton to Hickman CL	1.6	No	No	1927	1931	250	325		Not in 1945	Pliocene and Loess Recent Alluvium	
	Hickman	65	FA 146 CS (Hickman)			Graves CL-Fulton CL	3.3	No	No	1927	1931	200	300				
1	Fulton	43	FA 131 AFS (Fulton)	U.S. 51	Fulton-Clinton	CL Fulton-Hickman CL	6.4	No	No	1927	1930	206	319		Not in 1945	Loess	
1	Henderson	61	FA 51 BCS (Henderson)	U.S. 60	Henderson-Morganfield	Hender.-Union CL	11.6	No	No	1929	1931	350	700		Not in 1945	Pennsylvanian, Loess and Recent Alluvium	
	Union	69	FA 62 AS (Union)			Morgan.-Henderson CL	9.2	No	No	1922	1931	375	570				
	Henderson	213	DA-WR 902 (Henderson)			Approach to Highland Cr. Br.	0.5	120	20	1943	1943	---	800				
1	Christian	91	FA 93 AS-FA 44 AS	U.S. 68	Hopkinsville-Cadiz	CL Hopkins.-Trigg CL	10.2	No	No	1924	1932	250	308		Not in 1945	St. Louis, Fredonia, Ohara Ls (Miss.)	
1	Marshall	97	FAE 163 AS 2 (Mars.)	U.S. 68	Paducah-Benton	McCr.CL-4 mi. N. Benton	10.1	No	No	1929	1933	200	360		Not in 1945	Plio-Pliestocene	
	McCracken	149	FA 163 CGS (McCr.)			Riedland-1500' S. of Overpass	1.3	90	30	1937	1937	---	550				
3	Jefferson	176	FA 26 AIGS (Jeff.)	U.S. 31W	Louisville-Elizabethtown	Waverly Hill-Orell	5.1	90	30	1939	1939	---	1600		Yes	St. Louis Ls (Meramec Miss.) and Loess	
		183	FA 26 A5GS (Jeff.)			Orell-Nr. Kosmosdale	3.7	90	30	1939	1939	---	1520				
	Hardin	207	DA-WR 3 (Hardin)			Etown to Radcliffe	10.7	120	20	1942	1943	---	1000				
3	Hardin	208	SN-FA 169 F2 (Hardin)	U.S. 31W	Elizabethtown-Munsfordville	CL Etown to Nolin Riv.	7.3	120	20	1942	1942	---	535		Yes	Meramec Series (Miss.)	
		211	SN-FA 169 C2 (Hardin)			Cox Creek to Nolin Riv.	0.6	120	20	1943	1943	---	500				

Table 2 - Detailed Data on Roads Selected (Continued)

District	County	Code No.	Project No.	Route No.	Road	Location	Length	Joints		Year Graded	Year Paved	Truck Traffic			Pumping	Geologic Areas	Soil Area
								Expan.	Contrac.			1938	1945	1947			
3	Hardin			U.S. 31 W	Elizabethtown-Louisville	From Radcliff-Jeff CL	13.0								Yes	St. Louis Ls & Loess	
3	Oldham	36	FA 194 CS (Oldham)	U.S. 42	Louisville-Bedford	Jeff. CL to East	7.2	No	No	1928	1931	360	532		Yes	Silurian, Devonian, Richmond (Ordivician), and Loess	
		37	FA 194 AS (Oldham)			From above-Henry CL	8.6	No	No	1930	1931	400	380				
		38	FA 194 BS (Oldham)			From Henry CL-West	3.5	No	No	1929	1931	400	361				
	Henry	39	FA 194 DS-FA 145 CS			Old.CL-Trimble CL	1.1	No	No	1928	1930	400	380				
	Trimble	40	FA 145 AS (Trimble			Henry CL-Bedford	8.1	No	No	1926	1930	300	400				
	Jefferson	144	FA 194 HS (Jefferson)			CL Louisville-Taylor Mn.	1.9	90	30	1936	1937	608	832				
		164	FA 194 ES-FA 194 FS 2			Taylor Mn-Harrods Cr.Br.	4.3	90	30	1935	1938	---	720				
		196	SN-FA 194-E3 F3 L2			Taylor Mn-Oldham CL	6.6	120	60	1937	1941	---	500				
3	Hardin	77	FA 203-AS (Meade-Hardin)	U.S. 60	Brandenburg-Louisville	From Grahamton-Tip Top	3.1	No	No	1931	1932	240	405		Not in 1945	St.Louis Ls (Miss.)	
3	Jefferson	126	NRH 117 CDS (Jeff.)	U.S. 60	Frankfort-Louisville	Middle.-Shelby CL	7.0	90	30	1934	1934	560	640		Yes	Silurian, Devonian, Ordivician (Richmond, Maysville, Eden, Cynthiana)	Eden, Fairmount
		152	FA 117 JGS (Jeff.)			Middle.-CL Louisville	6.5	90	30	1938	1938	---	960				
	Shelby	155	FA 117 ABFS (Shelby)			CL Shelbyv.-Jeff. CL	9.6	90	30	1937	1938	---	1000				
		202	SN-FA 172 CS (Shelby)			CL Shelbyv.-Nr.Frnkln CL	11.7	120	60	1941	1942	---	644				
		203	SN-FA 172 A3D2			2d St.Frnkft.-Nr.Shelby CL	7.8	120	60	1941	1941	---	600				
3	Jefferson	1	FA 18 (Jefferson)	U.S. 150	Louisville-Bardstown	From CL Louisville-S.	4.5	30	No	---	1920	700	917		Not in 1945	Devonian, Silurian and Richmond (Ordivician)	
		3	FA 50 (Jefferson)			From above-Fairmont Sch.	4.5	30	No	---	1922	400	940				
		12	FA 50 B (Jefferson)			Fairmont Sch.-Bullitt CL	3.8	No	No	---	1925	450	620				
5	Scott	171	FA 174 ABGS (Scott)	U.S. 25	Williamstown-Georgetown	Williamstown-Georgetown	5.2	120	60	1938	1938	---	725		Yes	Eden, Cynthiana, Trenton (Ordivician)	Eden, Fairmount, Maury
4	Grant		FA 114 AS (Grant)				5.2										
			FA 114 (Grant)				5.5										
5	Scott		FA 115 B (Scott)				7.1										
			FA 115 AS (Scott)				8.4										
4	Kenton		FA 36 AB (Kenton)	U.S. 25	Florence-Covington		4.3								No	Maysville (Ordivician)	
			FA 96	U.S. 42			4.1										
			FA 100				0.3										
			FA 82				5.1										
4	Campbell	193	FA 320 G1 (Campbell)	U.S. 27	Newport-Alexandria	Ft.Thomas-Cold Springs	3.1	120	30	1941	1941	---	720		Not in 1945	Maysville (Ordivician)	
4	Boone	30	FA 168 CS (Boone)	U.S. 42	Florence-Warsaw	Jct.U.S.25-Union	5.4	No	No	1928	1929	300	784		Yes	Maysville and Richmond (Ordivician) Recent Alluvium	
		33	FA 168 DS (Boone)			Union-near Beaverlick	4.5	No	No	1928	1929	320	812				
		34	FA 168 AS (Boone)			Gallatin CL-Nr. "	5.5	No	No	1930	1930	360	616				
	Gallatin	35	FA 168 BES (Gallatin)			E. CL Warsaw-Boone CL	9.6	No	No	1929	1930	250	342				
4	Gallatin	70	FA 198 AS-FA 168 FS	U.S. 42	Warsaw-Bedford	Carrol CL-CL Warsaw	7.2	No	No	1931	1931	200	306		Yes	Richmond (Ordivician) and Recent Alluvium	
	Carroll	80	SP 13 DS (Carroll)			Jct. SR 36-Trimble CL	4.6	No	No	1930	1931	---	304				
		73	FA 198 BS (Carroll)			Ghent-Gallatin CL	2.7	No	No	1931	1931	200	297				
		101	SP 13 ECS (Carroll)			Carrollton-Ghent	6.9	No	No	1932	1932	270	360				
	Trimble	72	FA 197 AS (Trimble)			Bedford-Miller's Brnch	4.4	No	No	1931	1931	225	324				
		79	SP 13 DS (Trimble)			Miller's Br.-Carroll CL	1.9	No	No	1931	1931	225	306				
5	Madison	7	FA 49 (Madison)	U.S. 25	Richmond-Lexington	CL Richmond - North	7.0	30	No	---	1924	700	972		Yes	Eden, Maysville and Richmond (Ordivician)	
		132	NRH 124 AS (Madison)			Above-Clays Ferry Bridge	3.4	90	30	1935	1935	650	840				

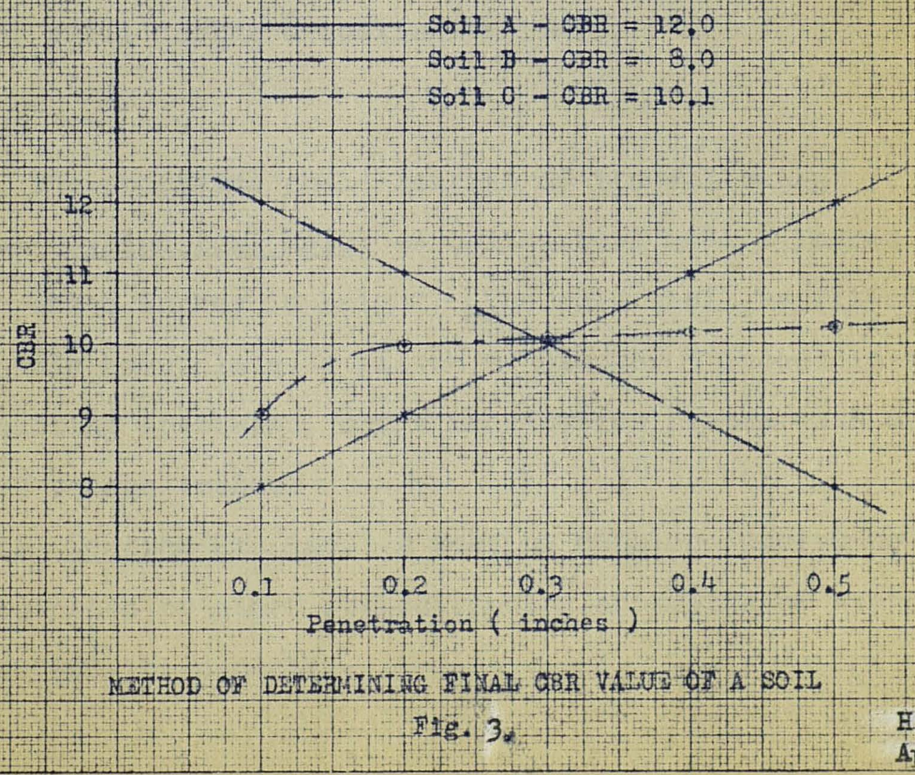
Table 2 - Detailed Data on Roads Selected (Continued)

District	County	Code No.	Project No.	Route No.	Road	Location	Length	Joints		Year Graded	Year Paved	Truck Traffic			Pumping	Geologic Area	Soil Area
								Expan.	Contrac.			1938	1945	1947			
5	Madison	165 214	FA 299 CGS (Madison) SN-A-FA 299 D1	U.S. 25	Richmond-Mt. Vernon	L&N RR - to South 1 mi. S. Richmond-Terrill	1.6 3.0	90 120	30 20	1938 1943	1938 1943	--- ---	1190 900		Yes	Richmond (Ordivician) Silurian & Devonian	
5	Fayette Clark	2 157 4	FA 2A (Fayette) FA 17 AGS (Clark) FA 2B (Fayette)	U.S. 60	Lexington-Winchester	CL Lexington-Jct. Co. Rd. 3.5 mi. West of Clark CL CL Winchester-Fayette CL Above to Clark CL	6.4 6.0 3.6	No 90 30	No 30 No	--- 1937 ---	1921 1937 1923	600 --- 500	770 750 600		Yes	Trenton, Cynthiana and Eden (Ordivician)	Loradale, Mercer
5	Woodford Fayette	166 169	FA 173 AGS (Woodfd) FA 173 CGS (Fayette)	U.S. 60	Lexington-Versailles	Lexington-Versailles W. C.L. Lex-Woodfd CL	4.0 7.1	120 120	30 30	1938 1938	1938 1939	--- ---	1250 1250		Slight	Trenton (Inner Blue-grass)	Maury
6	Johnson Floyd Johnson	29 59 60	SP 6C (Johnson) FA 133 ACS (Floyd) FA 133 CS (Johnson)	U.S. 23	Paintsville-Prestonburg	Paints. Depot-Jct. 302 NCL Preston.-John.CL Floyd CL to VanLear	1.4 5.8 3.8	No No No	No No No	1926 1925 1927	1927 1931 1931	700 400 400	1026 600 700		Not in 1945	Pottsville (Penn.)	
6	Floyd	83	FA 132 CS (Floyd) & FA 237 BS	U.S. 23	Prestonburg-Pikeville	CL Prestonburg to Bridge at Allen	8.6	No	No	1928	1932	550	798		Not in 1945	Pottsville (Penn.)	
6	Boyd	115	NRH 201 AS (Boyd)	U.S. 23	Ashland-Greenup	CL Ashland to Greenup CL	1.3	No	No	1933	1933	850	2500		Not in 1945	Pottsville (Penn.)	
6	Carter	14	FA 13 (Carter)	U.S. 60	Grayson-Olive Hill	Grayson-Olive Hill	15.1	No	No	1921	1926	300	372		Not in 1945	Pottsville (Penn.) Osage (Miss.)	
6	Letcher	27	SP 6 F (Letcher)	U.S.119	Jenkins-Whitesburg	From Jenkins to Seco	7.5	No	No	1925	1927	125	496		Not in 1945	Pottsville (Penn.)	
6	Perry	81	SP 4 AS and FA 128 HS (Perry)	S.R. 15	Hazard-Whitesburg	1000' West CL Hazard to Bridge at Glomar	3.1	No	No	1925	1931	425	812		Not in 1945	Pottsville (Penn.)	
6	Floyd	121 145	NRH 237 FS (Floyd) NRH 237 F1S FA 237 GS (Floyd)	S.R. 80	Allen-Lackey	River Bridge to 2 mi. south of Allen Above to 0.5 mi. West of Dinwood	2.4 3.6	No 90	No 30	1929 1929	1934 1937	333 ---	722 684		Not in 1945	Pottsville (Penn.)	
7	Laurel Rockcastle	11 199	FA 29 E (Laurel) SN FA 70 B2 (Rockc.)	U.S. 25	London-Mt. Vernon	Near Victory-Rock. CL Ct.house Mt. Vernon-Lndn.	5.5 6.3	No 120	No 60	1923 1941	1925 1942	350 ---	616 560		Yes	Pottsville (Penn.) Meramec (Miss.)	
7	Pulaski	66	SP 22 ES (Pulaski)	U.S. 27	Somerset-Whitley City	CL Somerset to Bridge at Burnside	6.3	No	No	1926	1930	250	512		Not in 1945	Meramec and Chester (Miss.)	
7	Harlan	18	FA 151 A (Harlan)	U.S.119	Harlan-Pineville	CL Harlan to near Wilhoit	4.5	No	No	1925	1926	350	552		Not in 1945	Pottsville (Penn.)	
2	Daviess	107	FAE 74 AS, FAE 106 AS	U.S. 60	Owens.-Henderson		7.4										
2	Daviess	47	FA 105 ABS	U.S. 60	Owens.-Hawesv.		8.3										
2	Daviess			S.R. 71	Owens.-Hart		6.3										



ZEROING OF LOAD VS. PENETRATION CURVE

Fig. 2.



METHOD OF DETERMINING FINAL CBR VALUE OF A SOIL

Fig. 3.

H.M.R.L.
April 12, 1947

Annex 2

PROCEDURE FOR CBR TEST

The following procedure is that followed by the Testing Laboratory, Kentucky Highway Department, in conducting the CBR test. It is, essentially, the same as the procedure outlined by T. E. Stanton on pages 109 to 116 in "Procedures for Testing Soils", Committee D-18, ASTM, dated September, 1944. Both the text and arrangement of Mr. Stanton's procedure have been followed closely. (* denotes changes in Mr. Stanton's procedure).

Scope

1. This method of test is intended to determine:

(a) The relative bearing value (bearing ratio) of untreated base, sub-base and subgrade material at optimum moisture and maximum density, and also after soaking the compacted specimens.

*(b) The extent to which subgrade and base materials will expand or swell during a soaking period.

Apparatus

2. The apparatus shall consist of the following:

(a) Cylindrical Mold. -A cylindrical mold 6 inches in diameter and 8 inches in height. The mold shall be fitted with a detachable base plate, a piston or plunger 5 inches in height for compacting specimens, and a penetration piston with an end area of 3 square inches.

(b) Testing Machine. -A testing machine consisting of a hydraulic press or other static loading apparatus of approximately 60,000-lb. capacity.

(c) Scale. -A scale or balance of 20-kg. capacity sensitive to 1 g.

*(d) Plate. -A perforated plate with an adjustable stem and a 15-lb. weight.

(e) Dials. -A dial or other suitable gage for measuring the penetration of the 3 square inch piston, and a dial or gage mounted in a tripod for measuring the expansion of the specimen during the soaking period.

(f) Water Tank. -A suitable water tank or vat for immersing the specimens during the soaking period.

(g) Drying Oven. -A suitable drying oven with forced ventilation.

(h) Miscellaneous Apparatus. -A depth gage graduated in 0.01 inches, mixing bowl, graduates, spatula, and spoons.

Sample

* 3. A representative sample of sufficient size to make a compacted cylinder(at maximum density) 6 inches in diameter by 4 inches in height shall be oven dried to constant weight at a temperature of 100° to 104°C. The dried material shall be separated into material retained on No. 4 sieve and that passing the No. 4 sieve. The material retained on the 3/8 inch sieve will be replaced by an equivalent weight of material retained on the No. 4 and passing the 3/8 inch sieve.

Compacted Test Specimen

*4. (a) A test sample of the material prepared in paragraph 3 above, shall be weighed to the nearest five grams, in a calculated quantity sufficient to give a compacted sample (at maximum density) 4 inches in height.

(b) The sample shall be mixed with the amount of water (optimum moisture content) giving the maximum dry weight per cubic foot and lightly temped into the tared mold and then compacted to maximum dry weight per cubic foot under a load of 2000 psi. In applying the increment of load between 1000 and 2000 psi., the head of the testing machine or the hydraulic press shall be operated at the rate of approximately 0.05 inch per minute. A static load of 2000 psi. shall be maintained on the sample for one minute and then gradually released during a period of about twenty seconds.

(c) The mold shall be removed from the testing machine or hydraulic press and the height of the compacted specimen measured with the depth gage to the nearest 0.01 inch. The dry weight per cubic foot of the specimen shall be calculated from the height and diameter of the specimen and the dry weight of the sample.

Penetration of Compacted Specimen Before Soaking

*5. The compacted specimen, retained in the mold, shall be placed in the testing machine and tested by penetrating with the small piston (end area of 3 square inches). A five pound weight is used during penetration test in order to partially contain sample, as well as to center the load. Before starting the penetration test, the piston shall first be placed on the center of the compacted specimen and firmly seated by applying an initial total load of ten lbs. after which the dial shall be set to zero. During the penetration test, the head of the testing machine shall be operated at the rate of 0.05 inch per minute and the total load in pounds and the unit load in

pounds per square inch shall be recorded at penetrations of .010, .025, .050, .075, .1, .2, .3, .4, and .5 inches.

Expansion

6. *(a) After completing the penetration test for the compacted condition, the top of the specimen shall be loosened to a depth of approximately 1 inch with a screwdriver or suitable rod. The mold shall then be turned upside down and the specimen recompacted under a load of 2000 psi. applied as previously specified in section 4 (b).

*(b) The height of the recompacted specimen shall be recorded to check the height and the dry weight per cubic foot of the specimen as originally compacted.

*(c) The perforated plate is then placed on top the sample, followed by a 15-lb. weight. The gage and tripod assembly shall next be set on the mold and the stem on the perforated disc adjusted to zero gage reading. After removing the gage, the mold assembly is placed in a water tank with overflow arrangement that will maintain the water level approximately 1 inch above the top of the mold.

*(d) The specimen shall be soaked until the swell is less than .003 inch per twenty-four hours. The expansion will be measured each day with the gage and tripod assembly and the results recorded in inches to three decimal places.

*(e) After the swelling period, the specimen shall be removed from the tank, the 15-lb. weight removed, and the mold drained of all excess water that will drain off in one minute. The filter paper and perforated plate will then be removed, the open areas of the mold dried, and the specimen and mold weighed

to determine the moisture content.

Penetration of Soaked Specimen.

7. The soaked specimen shall be tested for penetration as specified in section 5.

Moisture Content

8. A sample shall be taken from the top of the specimen to a depth of 1 inch, weighed, and dried to constant weight at 100° to 104° C. The moisture content of this portion of the material, as tested for bearing after soaking, shall be recorded.

Calculation of Bearing Ratio

9. *(a) The bearing ratio (relative bearing value) of the material in both the original and subsequent soaked condition shall be calculated in percentage of the following standards for each increment of penetration.

Penetration (inches)	Standard Load (psi.)
0.1	1000
0.2	1500
0.3	1900
0.4	2300
0.5	2600

The load for each increment is obtained after zeroing the test data. Since the initial readings are subject to surface irregularities, it has been found necessary to correct the load-deflection curve as illustrated in Fig. 2.

*(b) The bearing ratio of a material is not arbitrarily set at any increment of penetration. The "trend" of the CBR values for the soil are taken as indicative of field performance. Fig. 3 illustrates the various types of CBR versus penetration curves, and the CBR which would be used in each case.

Report

*10. The report for the CBR test consists of the CBR value. Data such as gradation, Proctor results, and routine test results form the bulk of the report. The foregoing conditions of testing are assumed to have been followed unless otherwise noted.

The method of determining the CBR value outlined in paragraph 9(b) above, will be used in this investigation. In addition, the CBR will be determined by Mr. Stanton's method; i.e. the lowest value obtained for any increment of penetration.

OFFICES OF KENTUCKY HIGHWAY PATROL

CENTRAL HEADQUARTERS—FRANKFORT

Mayfield	Williamstown
Clinton	Florence
Paducah	Cynthiana
Princeton	Georgetown
Murray	Carrollton
Henderson	Richmond
Morganfield	Paris
Owensboro	Winchester
Greenville	Mt. Vernon
Madisonville	Danville
Bowling Green	Ashland
Hopkinsville	Morehead
Louisville	Pikeville
Elizabethtown	Hazard
Brandenburg	Harlan
West Point	London
Springfield	Somerset
Campbellsville	Albany
Greensburg	Jamestown
	Columbia

HIGHWAY DISTRICT OFFICES

CENTRAL HEADQUARTERS—FRANKFORT

1. Paducah
2. Bowling Green
3. Louisville
4. Covington
5. Lexington
6. Ashland
7. Somerset

Additional or special Road condition and route information will be supplied when requested of

DIVISION OF PLANNING
DEPARTMENT OF HIGHWAYS
New State Office Building
Frankfort, Kentucky

YOUR FRIEND THE HIGHWAY PATROLMAN
ADVISES THAT FOR SAFETY'S SAKE YOU—
CULTIVATE THE HABIT OF CAREFUL DRIVING

Keep your car under control at all times.
Be sure brakes are in good working order.
Dim your lights when approaching other cars, unless your headlights are equipped with a thoroughly effective non-glare device. Glaring headlights are murderously dangerous.
Keep on the right side of the roadway; don't straddle or hug the center line.
Don't pass another car unless you can see that the distance ahead is clear for a safe passing distance. Remember this rule on hills and curves.
Proceed cautiously at intersections, and when meeting pedestrians.
Don't permit passengers or merchandise to crowd the driver's seat.
Give proper hand signal when about to slow down, stop, or turn right or left.

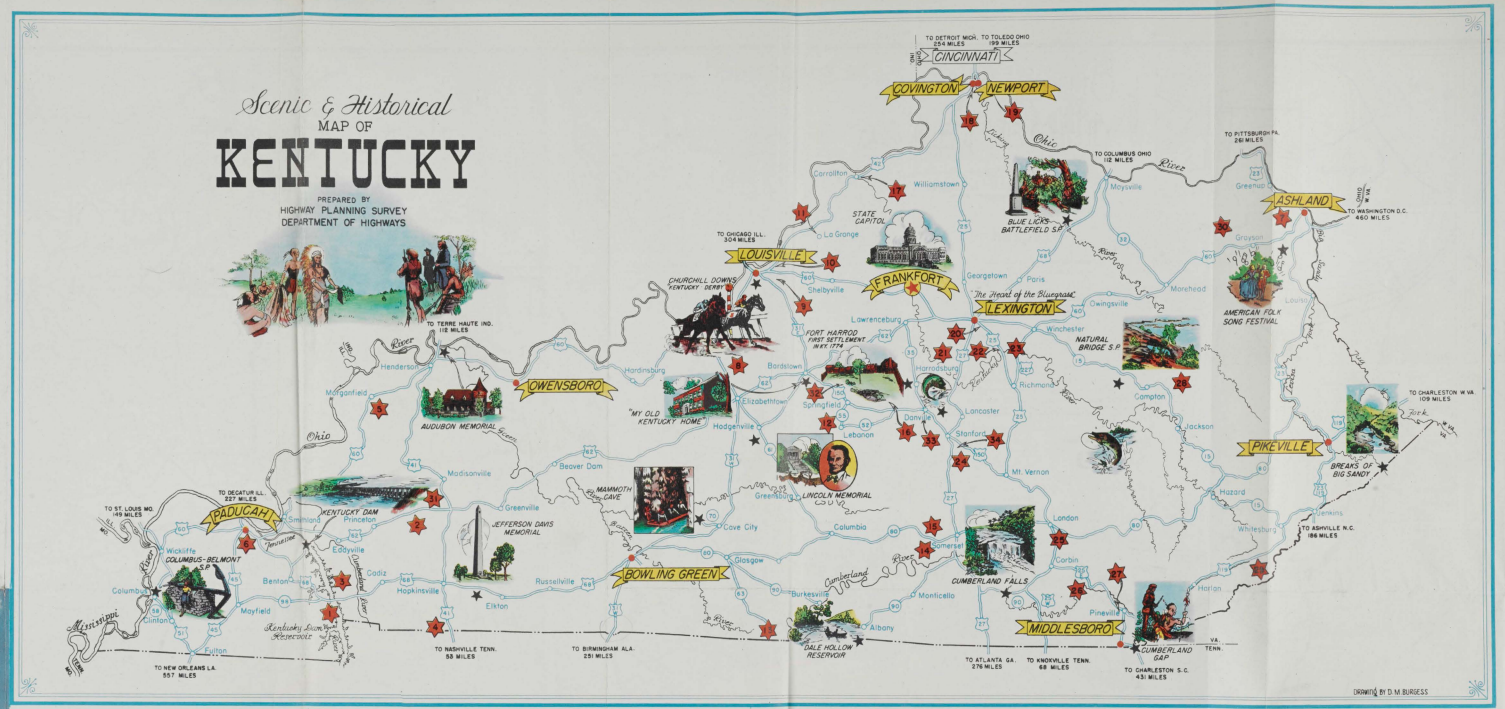
USE THESE HAND SIGNALS

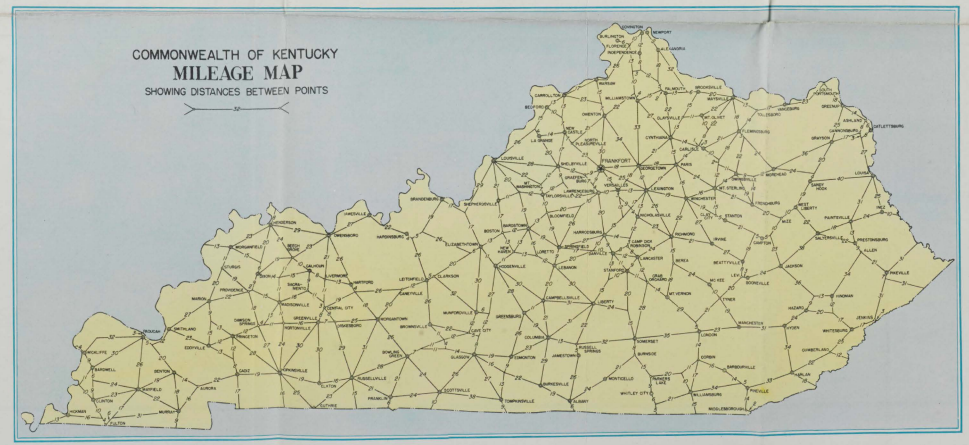
OBSERVE THESE MOTOR VEHICLE LAWS

Non-residents: exemption, Reciprocal, for passenger vehicles, where laws of home state have been complied with.
Speed—No operator of motor vehicle shall drive at greater speed than is reasonable and prudent, having regard for traffic and for condition and use of highway.
Closely built-up business sections—Speed 20 miles per hour. Resident portions—Speed 25 miles per hour. Unobstructed highway—Speed 45 miles per hour.
Headlights—Non-glare law in effect.
Hitch-hiking prohibited.
Duty to report accidents—Any person having an accident which involves death, injury, or property damage to the extent of $50.00, shall make a written report of same to the nearest Kentucky Highway Patrol Headquarters within 24 hours.
See list of Headquarters on inside cover.

OBTAIN YOUR DRIVER'S LICENSE

Persons operating motor vehicles must have their Driver's or Operator's Licenses in their immediate possession.
Your Driver's License is valuable. It gives you the privilege of using the roads as long as you drive carefully.





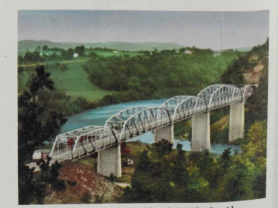
POINTS OF INTEREST SHOWN ON PICTORIAL MAP

1. **Kentucky Lake State Park** on the shores of the great artificial lake formed by Kentucky Dam across the Tennessee River at Gilbertsville.
2. **Jones-Kenney Game Refuge and Pennyrile Forest State Park.**
3. **Kentucky Woodlands Wild Life Refuge (Federal).**
4. **Camp Campbell**—8th, 12th, 14th, 20th Armored and 10th Infantry Divisions of World War II trained here.
5. **Camp Breckinridge**—World War II training camp for Triangular Infantry Divisions.
6. **Birthplace of Irvin S. Cobb,** the famous humorist.
7. **McGuffey Log School**—A memorial to the author of the McGuffey Readers.
8. **Fort Knox**—Home of 1st Armored Division of World War II. Nation's gold repository.
9. **Bowman Field**—Municipal Airport for City of Louisville.
10. **Zachary Taylor Monument**—Tomb of General Zachary Taylor and National Cemetery.
11. **State Prison**—Modern penal institution of the medium security type.
12. **National Cemetery.**
13. **Old Mulkey Meeting House State Park**—Oldest church in southern Kentucky. Built in 1794.
14. **Zollicoffer Park**—Site of Battle in which General Zollicoffer was killed.
15. **National Cemetery.**
16. **Perryville Battlefield State Park**—Here in 1862 occurred one of the bloodiest battles of the Civil War.
17. **Butler Memorial State Park**—Homestead of General Orlando Butler of the Indian and Mexican Wars. Tourist accommodations available.
18. **"Monte Casino"**—Smallest church in world.
19. **Fort Thomas**—Permanent Army Post.
20. **"Ashland"**—Home of Henry Clay from 1806 until his death in 1852.
21. **High Bridge Park** about two miles east of Shakertown. The highest railroad bridge in the world across a navigable stream.
22. **Clays Ferry Bridge**—A modern, unusually high structure across the beautiful Kentucky River and its valley.
23. **Boonesboro Fort**—Site where Daniel Boone built to first fort in 1775.
24. **Halls Gap**, scenic height six miles south of Stanford. Overlook with fine view to North, East and West.
25. **Levi Jackson Wilderness Road State Park**—This park marks the scene of one of the bloodiest Indian Massacres in History. Known as "Defeated Camp."
26. **Walker Memorial State Park** honors Dr. Thomas Walker The man who preceded Daniel Boone into Kentucky.
27. **Pine Mountain State Park**—Scene of annual mountain Laurel Festival.
28. **Sky Bridge**—Natural stone formation near Slade.
29. **"Black Mountain"**—Highest Point in Kentucky. Elevation 4,150 feet.
30. **Cave Area** (Eastern Kentucky) between Olive Hill and Grayson containing Carter and Cascade Caves.
31. **Dawson Springs State Park**—Beautiful woodland spot. Lake, with Bathing Beach, Bath-houses, Boating, etc. Furnished cabins.
32. **Lincoln Homestead State Park** — Abraham Lincoln, grandfather of the president settled here in 1782.
33. **Dr. Ephriam McDowell and Jane Todd Crawford Memorial.** Home of Dr. Ephriam McDowell who performed here in 1809 the first ovariotomy operation in the world the patient was Jane Todd Crawford. Also contains Dr. Weisinger Memorial to Constitution Square—reproduction of the log cabin in which the nine constitution conventions were held.
34. **First Brick House West of Allegheny Mountains.** William Whitley Home.

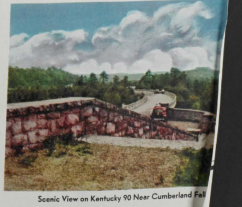

Separation for Civilian and Military Traffic at Fort Knox

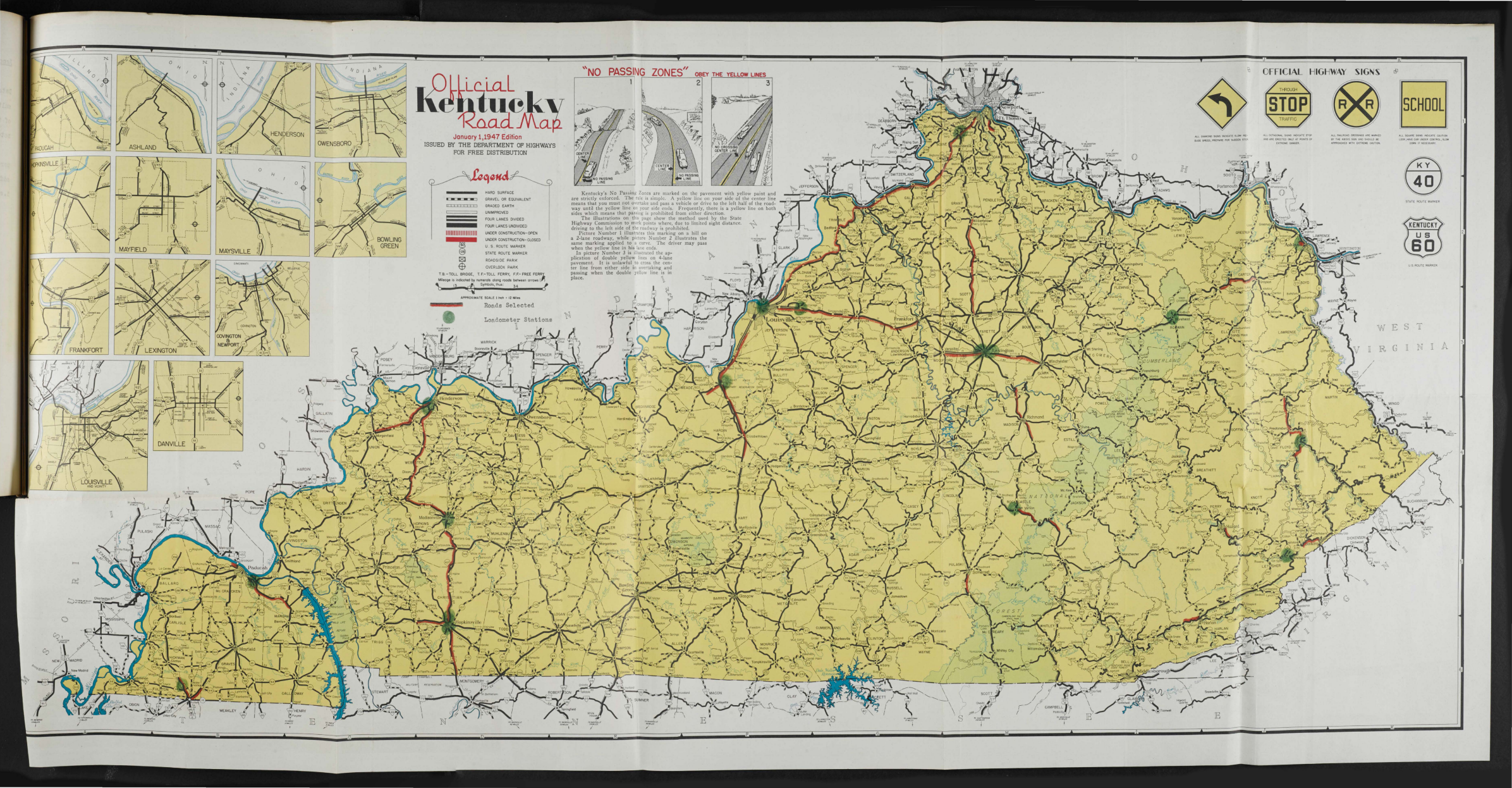

Crossing Barren River North of Bowling Green on U. S. 31-W


Brooklyn Bridge on U. S. 68 Near Historic Shakertown


U. S. 27 Bridges the River and Tunnels the Hill at Burnside


U. S. 60 in Central Kentucky


Scenic View on Kentucky 90 Near Cumberland Fall


Official
Kentucky
Road Map
January 1,1947 Edition
ISSUED BY THE DEPARTMENT OF HIGHWAYS
FOR FREE DISTRIBUTION
Legend
HARD SURFACE
GRAVEL OR EQUIVALENT
GRADED EARTH
UNIMPROVED
FOUR LANES DIVIDED
FOUR LANES UNDIVIDED
UNDER CONSTRUCTION–OPEN
UNDER CONSTRUCTION–CLOSED
U. S. ROUTE MARKER
STATE ROUTE MARKER
ROADSIDE PARK
OVERLOOK PARK
T.B.–TOLL BRIDGE, T.F.–TOLL FERRY, F.F.–FREE FERRY
Mileage is indicated by numerals along roads between arrows
Symbols, thus: 34
APPROXIMATE SCALE 1 Inch = 12 Miles
Roads Selected
Londometer Stations
"NO PASSING ZONES" OBEY THE YELLOW LINES
1
2
3
CENTER LINE
NO PASSING LINE
NO CROSSING CENTER LINE
Kentucky's No Passing Zones are marked on the pavement with yellow paint and are strictly enforced. The rule is simple. A yellow line on your side of the center line means that you must not overtake and pass a vehicle or drive to the left half of the road-way until the yellow line on your side ends. Frequently, there is a yellow line on both sides which means that passing is prohibited from either direction.
The illustrations on this page show the method used by the State Highway Commission to mark points where, due to limited sight distance, driving to the left side of the roadway is prohibited.
Picture Number 1 illustrates this marking on a hill on a 2-lane roadway, while picture Number 2 illustrates the same marking applied to a curve. The driver may pass when the yellow line in his lane ends.
In picture Number 3 is illustrated the application of double yellow lines on 4-lane pavement. It is unlawful to cross the center line from either side in overtaking and passing when the double yellow line is in place.
OFFICIAL HIGHWAY SIGNS
ALL DIAMOND SIGNS INDICATE SLOW-TO-SIDE SPEED, PREPARE FOR SUDDEN STOP
THROUGH
STOP
TRAFFIC
ALL OCTAGONAL SIGNS INDICATE STOP AND ARE ERECTED ONLY AT POINTS OF EXTREME DANGER.
R R
ALL RAILROAD CROSSINGS ARE MARKED BY THE ABOVE SIGN AND SHOULD BE APPROACHED WITH EXTREME CAUTION.
SCHOOL
ALL SQUARE SIGNS INDICATE CAUTION. LOW JAWS CAR UNDER CONTROL, SLOW DOWN IF NECESSARY.
KY
40
STATE ROUTE MARKER
KENTUCKY
US
60
U.S. ROUTE MARKER
PADUCAH
ASHLAND
HENDERSON
OWENSBORO
HOPKINSVILLE
MAYFIELD
MAYSVILLE
BOWLING GREEN
FRANKFORT
LEXINGTON
COVINGTON & NEWPORT
LOUISVILLE AND VICINITY
DANVILLE
Louisville
Frankfort
Lexington
Owensboro
Henderson
Paducah
Hopkinsville
Mayfield
Bowling Green
Madisonville
Somerset
Middlesboro
Ashland
Maysville
Covington
Newport
Danville
WEST VIRGINIA
VIRGINIA
ILLINOIS
INDIANA
OHIO
TENNESSEE
MISSOURI